LOW-LEVEL WASTE
(MAP ACTIVITY)

Purpose:

This lesson will describe current and future disposal of low-level nuclear waste. Plans of individual States for compliance with the provisions of the amended Low-Level Radioactive Waste Policy Act of 1980 will be presented. Sources of low-level waste and amounts disposed of will be examined at a national, State, and regional compact level. Students will also investigate relationships between volumes of waste and levels of radioactivity.

Concepts:

1. A national problem exists because there is an accumulation of nuclear waste.
2. The amended Low-Level Radioactive Waste Policy Act requires that the disposal of low-level nuclear waste be conducted by individual States or regional groupings of States known as compacts.

Duration of the Lesson:

Two 50-minute class periods

Objectives:

As a result of participation in this lesson, the learner will be able to:

1. list the two Federally licensed sites where commercial low-level waste is currently disposed of;
2. discuss provisions of the amended Low-Level Waste Policy Act of 1980 regarding each State's responsibilities for low-level waste disposal;
3. explain how the State he/she lives in will dispose of low-level waste after 1993;
4. construct a choropleth map showing amounts of low-level waste disposed of in 1993 at Federally licensed sites by State;
5. analyze patterns of disposal of low-level nuclear waste in the United States in 1993; and
6. analyze the relationship between volume and level of radioactivity of low-level waste.

Skills:

Analyzing, critical thinking, data transferring, discussing, evaluating, explaining, graphing, grouping, interpreting maps, labeling, listing, mapping, reading, sorting, synthesizing

Vocabulary:

Choropleth map, commercial, compact, cubic feet, Federally licensed sites, frequency diagram, geographic distribution, LLRWPA, Low-Level Radioactive Waste Policy Act of 1980, shallow land burial, spatial, thematic map, unaffiliated State

Materials:

Reading Lesson
Nuclear Waste: What Is It? Where Is It? (Optional), p. SR-9
Low-Level Waste, p. SR-11

Activity Sheets
Low-Level Waste Parts I and II, pp. 139-150
Low-Level Waste Compacts, December 1992, p. 143
Low-Level Waste Number Line, p. 145
Low-Level Waste Received at Disposal Sites - 1993 (blank U.S. map—If students use colors to indicate disposal by State, the same map can also be used to indicate compacts and unaffiliated States. If students use symbols to show disposal by States, they will need a second outline map for the compacts.), p. 147

Other
U.S. Map or Atlas (Optional)
Colored pencils (Optional but helpful in enabling students to put all information on one map)
Protractor
Calculator (Optional)

Background Notes
Low-Level Waste, p.63

Suggested procedure:

Student activities for this lesson are divided into two separate parts. In Part I, students use data provided to make a map of unaffiliated states and compacts formed for regional disposal of low-level waste; fill in a number line for state low-level waste volumes; and make a map of low-level waste inventories in the U.S. In Part II, students make circle graphs to show the percentages of low-level waste disposal from five sources.

Part I

A thematic map is about a single topic, such as inventories of spent fuel or disposal of low-level waste by State. Thematic maps with shaded or colored areas are choropleth maps. Their shading or coloring enables map readers to see patterns quickly, and for this reason, shading or coloring is progressively darker as data values increase.

The data on Low-Level waste received can be visualized in two ways: 1) arranging data on the provided number line (also called a frequency diagram) and 2) filling in the map according to the volume ranges specified by the legend. In this lesson, students will fill in the number line and the choropleth map about disposal of low-level nuclear waste using data taken from the table entitled *1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites* on the activity sheets entitled *Low-Level Waste*. Have the students fill in the number line first. The number line can be used to explain how the map legend was developed, or as an easy way to retrieve data when coloring the map.

Assign the enrichment activity entitled *Low-Level Waste*. The activity can be either an individual or group activity. To complete the activity, students will need copies of the instructions, including the table of disposal by State entitled *1993 Volumes of Low-Level Waste Received at Disposal Sites*, the *Low-Level Waste Number Line*, and either one or two copies of the outline map. Note that most of Part I of this enrichment activity is very similar to the enrichment activity entitled *Spent Fuel Inventories*. (See Days 4 & 5.) However, this activity requires students to complete two additional steps. In Step 4 of Part I, they must convert data to units of thousands of cubic feet, and in Part II, they must make a pie chart (circle graph).

- If students did not complete the activity entitled *Spent Fuel Inventories*, you may wish to begin by discussing the activity introduction, which describes thematic and choropleth maps and identifies for students the two main steps they will need to perform in order to complete the assignment – arranging data in the established categories on the number line and filling in the map to show low-level waste volumes by State.

- Filling in the data table and number line:

  Students should be able to complete the activity by following the directions on the activity sheet. They may find it helpful to do one or two examples for the data table in Step 3 and then assign States to the correct space on the number line. After students have finished through Step 4 of the activity directions, you may wish to initiate a class discussion about how the data was organized and how it provides well- distributed categories of volume spans. It is important that students understand that the data can be grouped into categories in more than one way. Students should understand that the categories do not have to represent equal numbers on the number line nor equal numbers of States. What they are trying to do is see a pattern in the distribution of low-level waste.

  Begin with the basic concept of compacts and completing the map, which will visually show students these regional agreements. Then, have students list low-level waste compacts and assign symbols or colors for each compact in the legend on the worksheet. Once the legend is prepared, have them fill in the map with postal abbreviations for states and the colors or symbols they picked to identify compacts.

  When moving onto the number line and inventory volume map parts of this activity, the following questions may be helpful in discussing the established categories. If students completed the activity entitled *Inventories of Spent Fuel*, some of these will be repetitive.

A. The states with spent fuel storage were divided into five categories. If only two categories were selected, what would the map show?

   (Probably, only the States that disposed of low-level waste in 1993 and the States that did not. With only two categories, a range cannot be shown.)

B. What additional information will the map reader gain from the map showing four categories?

   (The map reader will picture the range of low-level waste inventories.)

C. How many States disposed of no low-level waste in 1993 or disposed of less than 500 cubic feet? How should these States be shown on the map?

(Fifteen States either disposed of no low-level waste or less than 500 cubic feet of waste in 1993. They should be left blank on the map. Puerto Rico also disposed of no low-level waste in 1993 and should be left blank.)

D. On the number line, which categories have four or more States listed?

(0-10, 10-20, 30-40)

E. Which categories have only one State listed?

(40-50, 50-60, 60-70, 70-80, 80-90, 100-110)

F. Selecting symbols or colors:

Because one purpose of a choropleth map is to enable the map reader to see patterns quickly, symbols or colors selected should reinforce visually the range of data values, with darker symbols or colors representing greater data values. Some groups may need some help in thinking of symbols or in establishing a range of colors.

G. Students should fill in the legend with colors or symbols for the pre-established categories and fill in the map to show a pattern of low-level waste received by States.

H. When students and/or groups have completed the maps, discuss them. Ask as many students as possible to share with the class what they learned from the map.

The following questions may be helpful:

1. Ask students to explain why they think the State volumes were divided into these five categories.

   (Answers will vary)

2. Have students explain the significance of the symbols or colors they selected for use on their choropleth maps.

   (Answers will vary, but should include information such as darker colors or symbols represent greater data values.)

3. Ask students to describe to the class the overall significance of the maps they have constructed.

   (Answers will vary, but may include comment on the location of the three federally licensed sites where commercial low-level waste is currently disposed of, an indication of how much low-level waste is disposed of at federally licensed sites and where it comes from, and an analysis of patterns of disposal of low-level waste in the United States in 1993.)

Part II

A. Students are instructed to study and finish the partially complete pie chart for the enrichment activity *Low-Level Waste Disposal by State* before figuring the percentage of low-level waste disposed of by their home State. You may wish to assign a different State to each student and have students share and compare results.

B. Students should be able to complete Part II of this activity by following directions and filling in the tables on the activity sheet. A calculator will be helpful in finding the decimal fractions and converting percents to degrees. It may be helpful to do the first conversion as a group. For example, for the percentage of volumes of waste from academic:

<u>12,172</u> ÷ <u>792,182</u> = <u>0.0154</u>
Round <u>0.0154 to 0.015</u>
Convert to percent = <u>1.5</u>% (round to nearest half-percent)
Convert to degrees: <u>0.015 x 360</u>° = <u>5.5</u>°

C. When students have completed the pie charts, analyze the charts. The questions that follow may be helpful.

1. What percentage of low-level waste disposed of by your home State or the compact your State belongs to came from each category in <u>1993</u>?

   (Answers will vary)

2. Of the five sources of low-level waste listed (academic, government, industrial, medical, and utility) which was the heaviest producer of low-level waste in your area? Does this information tell you anything in particular about your home State?

   (Answers will vary)

3. After completing the map and pie chart activities on low-level waste, can you conclude why the U.S. Congress felt it was necessary to pass the Low-Level Radioactive Waste Policy Act and amendments?

   (Answers will vary, but should include comment upon the necessity to provide for a national disposal system to manage low-level wastes and making disposal of commercially generated low-level radioactive waste a responsibility of each State and encouraging the States to form interstate compacts to manage and dispose of low-level waste on a regional basis.)

D. Have students write, in a few sentences, what they have learned from this lesson.

Teacher Evaluation of Learner Performance:

Completion and discussion of the number line, activity map(s), pie charts, and written assignment on what has been learned will indicate comprehension.

LOW-LEVEL WASTE

Every State produces Low-Level Waste. However, there are only two commercial low-level waste disposal sites currently in operation. They are in Barnwell, South Carolina and Hanford, Washington.

Industrial low-level waste sources include, among others, radiochemical and pharmaceutical companies and manufacturers of smoke detectors and luminous dials. In March 1981, the Nuclear Regulatory Commission (NRC) removed some of the restrictions on the disposal of radioactive biomedical waste. This was done to decrease the volumes of very low-level radioactive waste shipped to NRC-licensed commercial disposal facilities from hospitals, laboratories, medical schools, and other institutions. Representative characteristics of this institutional waste indicate three distinct waste "streams" which can be categorized as nonbioresearch and medical. Bioresearch waste results mainly from chemical tracers used in animal studies, and medical waste comes from medical diagnostic and therapeutic practices.

Three commercial low-level waste disposal sites in the eastern United States (Maxey Flats, Kentucky; Sheffield, Illinois; and West Valley, New York) have been closed to further use. The closure of these three commercial low-level waste disposal sites resulted in increasing volumes of low-level waste being shipped to the two remaining operating sites in South Carolina and Washington. The increase prompted South Carolina to impose a cap on the volume of low-level waste that could be accepted at Barnwell. Eventually, a general concern developed that the responsibility for low-level waste disposal should not rest with so few States, and a coordinated national plan was needed.

The Low-Level Radioactive Waste Policy Act was passed in 1980, making each State responsible for its own low-level waste and encouraging formation of regional interstate compacts to deal with the disposal problem. The Act provided that any compact approved by Congress could restrict access to its low-level waste disposal facility and accept waste from only member States after January 1, 1986.

However, by 1984, it became evident that no new regional disposal facilities would be operating by the end of 1985. This gave rise to the Low-Level Radioactive Waste Policy Amendments Act, which continued to encourage interstate compact formation while requiring that non-sited (i.e., without an operating disposal site) States and compacts meet specific milestones leading to the operation of new regional facilities by January 1, 1993. As of 1994, these milestones had not been met by the affected States. Additionally, the Low-Level Radioactive Waste Policy Amendments Act established rates and limits of acceptance at the commercial disposal sites now in operation, as well as space allocations for utility wastes. The utilities are required to meet certain waste volume reductions during a 7-year transition period, which is provided for the opening of new low-level waste disposal sites under State compact arrangements. The full impact of the new law is being studied.

The States that comprise each compact and a list of unaffiliated States are given in this section for the enrichment activity entitled *Low-Level Waste Disposal by State.*

Science, Society, and America's Nuclear Waste **ENRICHMENT ACTIVITY**

LOW-LEVEL WASTE

Low-level nuclear waste and high-level nuclear waste have different characteristics and, therefore, are disposed of differently. Historically, some quantity of low-level radioactive waste has been generated in every State from a variety of commercial sources, including academic, government, and industrial research; manufacturing processes; medical diagnosis and therapy; and electricity generation. Currently, these wastes are disposed of at Federally licensed sites in Barnwell, South Carolina and Hanford, Washington. A third site, Beatty, Nevada, closed at the end of 1992, but still contains waste.

To provide a national disposal system to manage low-level wastes, the U.S. Congress passed the Low-Level Radioactive Waste Policy Act and amendments. These laws make disposal of commercially generated low-level radioactive waste a responsibility of each State. States are encouraged to form interstate compacts to manage and dispose of low-level waste on a regional basis. The District of Columbia and Puerto Rico must also comply with provisions of this law. Nine compact regions have been formed and ratified by Congress: Texas, Maine, and Vermont have agreed at the State level to form a tenth compact with Texas as the host State. This agreement has not been approved by Congress at this date. New York and Massachusetts have declared themselves independent host States. As of March 1994, three States, as well as Washington, D.C. and Puerto Rico, remain unaffiliated. Unaffiliated States and States in compacts without an operating disposal site are required to meet specific milestones and deadlines leading to the operation of new regional disposal facilities by January 1, 1993. However, as of 1994, these milestones had not been met by the affected States.

1993 Sources and Volumes of Low-Level Waste Received at Disposal Sites (Cubic Feet)

	Academic	Government	Industry	Medicine	Utilities	Total
APPALACHIAN COMPACT	**1,503**	**6,326**	**3,760**	**117**	**48,811**	**60,517**
Delaware	4	1	489	7	0	501
Maryland	1,256	5,984	770	9	3,346	11,365
Pennsylvania	228	341	2,489	101	45,465	48,624
West Virginia	15	0	12	0	0	27
CENTRAL COMPACT	**647**	**251**	**205**	**39**	**23,598**	**24,740**
Arkansas	16	81	0	19	2,774	2,890
Kansas	118	4	160	16	2,428	2,726
Louisiana	331	1	30	1	6,798	7,161
Nebraska	165	5	0	0	11,598	11,768
Oklahoma	17	160	15	3	0	195
CENTRAL MIDWEST COMPACT	**420**	**22**	**2,891**	**214**	**63,436**	**66,983**
Illinois	218	2	2,645	214	63,436	66,515
Kentucky	202	20	246	0	0	468
MIDWEST COMPACT	**2,435**	**49**	**4,207**	**52**	**13,380**	**20,123**
Indiana	272	11	684	0	0	967
Iowa	525	0	8	0	1,474	2,007
Minnesota	655	2	282	0	4,118	5,057
Missouri	534	0	1,041	4	1,610	3,189
Ohio	400	31	2,175	48	4,023	6,677
Wisconsin	49	5	17	0	2,155	2,226

Table Continued

	Academic	Government	Industry	Medicine	Utilities	Total
NORTHEAST COMPACT	**1,212**	**983**	**5,331**	**86**	**28,066**	**35,678**
Connnecticut	642	872	1,667	18	11,403	14,602
New Jersey	570	111	3,664	68	16,663	21,076
NORTHWEST COMPACT	**1,469**	**114,909**	**16,018**	**237**	**15,445**	**148,078**
Alaska	0	447	0	0	0	447
Hawaii	0	2,361	0	0	0	2,361
Idaho	300	23	2	0	0	325
Montana	0	0	0	0	0	0
Oregon	326	95,857	3,631	9	4	99,827
Utah	0	0	6,524	0	0	6,524
Washington §	843	16,221	5,861	228	15,441	38,594
Wyoming	0	0	0	0	0	0
ROCKY MOUNTAIN COMPACT	**326**	**0**	**12**	**0**	**38,333**	**38,671**
Colorado	326	0	0	0	38,333	38,659
Nevada	0	0	0	0	0	0
New Mexico	0	0	12	0	0	12
SOUTHEAST COMPACT	**2,727**	**51,699**	**120,851**	**1,340**	**99,275**	**275,892**
Alabama	10	214	187	21	12,645	13,077
Florida	184	143	813	74	11,312	12,526
Georgia	313	63	1,271	79	11,506	13,232
Mississippi	31	71	554	13	6,703	7,372
North Carolina	1,522	38	15,061	1,099	19,309	37,029
South Carolina §	243	8,513	8,315	5	18,401	35,477
Tennessee	320	6	82,364	44	1,924	84,658
Virginia	104	42,651	12,286	5	17,475	72,521
SOUTHWEST COMPACT	**115**	**10,511**	**3,560**	**419**	**13,366**	**27,971**
Arizona	0	5	0	0	8,148	8,153
California	115	10,493	3,560	419	5,218	19,805
North Dakota	0	4	0	0	0	4
South Dakota	0	9	0	0	0	9
UNAFFILIATED (Not members of any compact as of 1992)	**1,318**	**6,599**	**27,925**	**2,632**	**55,055**	**93,529**
Army Outside of U.S.	0	2,506	0	0	0	2,506
District of Columbia	0	0	0	0	0	0
Maine*	0	0	0	0	0	0
Massachusetts	200	3,384	4,819	131	16,431	24,965
Michigan	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0
New York	633	386	19,787	2,472	28,346	51,624
Puerto Rico	0	0	0	0	0	0
Rhode Island	0	0	0	0	0	0
Texas*	464	322	3,319	29	5,667	9,801
Vermont*	21	1	0	0	4,611	4,633
TOTAL	**12,172**	**191,349**	**184,760**	**5,136**	**398,765**	**792,182**

Note: Due to computer-generated rounding, totals may not add up exactly.

§ *Current location of disposal site. (Washington will host a site for the Northwest Compact and the Rocky Mountain Compact.)*

* *As of March 1994, Texas, Maine, and Vermont had agreed to form a tenth compact.*

Source: The 1993 State-by-State Assessment of Low-Level Radioactive Wastes Received at Commercial Disposal Sites *(DOE/LLW-205), September 1994.*